Potential of Small Modular Reactors

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UK Experience of Different Reactor Systems

Sodium-cooled fast reactors

1950
DFR

1960
PFR

1970

1980

1990

Present

Gas-cooled reactors

Magnox

Water-cooled reactors

SGHWR

HTR

Sizewell B PWR
UK Experience: Advanced Reactor Systems

- Experience with advanced fast and thermal reactors:
  - Gen III, III+, IV
  - Fast Reactors
  - HTGRs
  - SMRs
  - Molten Salt Reactors
  - Th fuelled based systems

- History of participation in international projects
  - European Fast Reactor development
  - Numerous European Framework 5, 6 & 7 projects
  - South African PBMR project
  - Generation-IV VHTR, SFR, and GFR systems

Present 2050 ?
The Carbon Plan: Sustainable Energy

- Legally binding 80% emission reduction by 2050
- Low carbon generation needed for:
  - Electricity
  - All transportation
  - Domestic and Industrial Heat, Light & Power
- Electricity grid grows from ~85 GWe to ~300GWe
- Generation sources Renewables, CCS and Nuclear
New Nuclear Build

- Westinghouse AP1000 [USA]
- Hitachi-GE ABWR [Japan-USA]
- Small modular reactor [?] → [?]
- Areva EPR [France-China]

Source: DECC
UK Nuclear Energy R&D

- Government recently announced a 5-year, £250M programme of nuclear R&D
- The UK’s Nuclear Innovation & Research Advisory Board (NIRAB) recommended research in 5 main areas to:
  - Build on UK skills, experience and facilities
  - Maintain a balance across the whole fuel cycle
  - Establish international co-operations

  **Programmes**
  1. Making the fuels of the future
  2. 21st century manufacturing
  3. Next generation reactor design
  4. Advanced spent fuel recycling
  5. Strategic toolkit
SMRs – Critical Characteristics

Compared with large nuclear stations
EPR 1,600Gwe:

• Lower generating capacity
  < 300 - 500MWe

• Simpler in design
  Fewer pipes and welds

• Less on-site construction
  Modular built in factories

• Faster construction times
  ~ 3 years

• Greater flexibility
  Load-following with renewables
  Dual use including district heating
  More potential sites
Range of SMR designs

- B&W mPower
- CNEA CAREM
- Martingale ThorCon
- Holtec SMR160
- Westinghouse SMR
- NuScale
- CNAE ACP-100
- KAERI SMART
- Moltex Energy SSR
- Thorium100 HTMR100
- X-Energy Xe100
- Urenco U-Battery

(Not to scale)
...And a range of fuel cycle options

- **Fuel type:**
  - iPWR: standard PWR fuel (shorter length)
  - HTR: fuel pellets (Triso)
  - MSR: fuel and coolant together

- **Accident tolerant fuel development**

- **Enrichment**
  - iPWR: < 5%
  - HTR: > 10%
  - MSR: < 5%

- **Uranium supply expected to be stable**

- **Waste management**
  - Modest increase in waste volume per MWh

- **Potential fuel supply from UK**
  - Urenco (enrichment)
  - Springfields Fuels Ltd (manufacture)
SMRs in the UK – Why?

Economic Driver

Economic driver: opportunity for UK content and IP

Detailed design

Manufacture

Nuclear fuel

Construction

Design for Manufacturing and Assembly (DfMA)
SMRs in the UK – Why?
Economic Driver

Economic driver: opportunity for UK content and IP

Estimated technology readiness level

7 - 9

Estimated time to deployment (years)

5 - 15

15 - 25

25+

A. LWR1
B. LWR2
C. LWR3

D. HTR1
E. HTR2
F. HTR3

G. SFR1
H. SFR2
I. SFR3

J. MSR1
K. MSR2
L. MSR3

M. GFR1
N. SCWR1
O. LFR1
SMRs in the UK – Why?
Economic Driver

Economic driver: international export opportunities

UK: 7 GWe
Global: 70 GWe

“Small Modular Reactors (SMR) Feasibility Study”, National Nuclear Laboratory, 2014
Economic driver: international export opportunities

Developing countries where:

- electricity needs are dispersed
- grid capacities are limited
- where there is a need to balance electricity production against the variable supplies of renewables
- deliver ‘dual use’, e.g. electricity alongside district heating or desalination

UK: 7 GWe
Global: 70 GWe
Energy driver: levelised cost of electricity
SMRs in the UK – Why?
Energy Driver

Energy driver: fit within the UK energy network

• Siting assessment
  • 250 potential sites
  • Up to ~70GWe

• SMR application
  • Baseload power
  • Variable power (load follow)
  • Duel use (district heating)
Summary

- UK has experience across a variety of reactor systems and fuel cycles
- New Nuclear Power Plant construction programme underway (16GWe)
- New Nuclear Energy R&D Programme underway – need for more than 16GWe?
- Advanced systems being studied and specifically how SMRs could enable more energy production based on key economic and energy drivers.